COMMUNICATION SYSTEM, TRANSMITTING APPARATUS AND TRANSMITTING METHOD, RECEIVING APPARATUS AND RECEIVING METHOD, UNBALANCE CODE MIXING METHOD AND MULTIPLE CODE DECODING METHOD

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CROSS REFERENCES TO RELATED APPLICATIONS

[0001]

The present document is based on Japanese Priority Document JP 2002-345041, filed in the Japanese Patent

10 Office on November 28, 2002, the entire contents of which being incorporated herein by reference. In addition, the present application is a related application of a PCT international application PCT/JP03/01583 and Japanese Patent Applications No. 2002-007959 and No. 2002-007958.

15

BACKGROUND OF THE INVENTION

[0002]

1. Field of the Invention:

[0003]

20 The present invention relates to a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing (UCM) method and a multiple code decoding method, which are operating under a multiple

25 access environment where a plurality of mobile terminals are in communication with a single base station simultaneously, and more particularly, to a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an

30 unbalance code mixing and a multiple code decoding method, which are to expand a capacity by canceling in- and out-

cell interference.

[0004]

More specifically, the present invention relates to a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing method and a multiple code decoding method, which are to increase a capacity by performing operations with a very short frequency reuse, more particularly, to a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing method and a multiple code decoding method, which are to increase a capacity by implementing one-frequency reuse using a non-spread spectrum cellular system.

[0005]

2.   Description of the Related Art:

[0006]

The cause of mobile communications was because electromagnetic waves were discovered, and thereafter, further researches and developments of the mobile communications have been made due to the necessity for communication with ships, airplanes and/or trains. Further, the subject of the mobile communications has been widened to cover a range of communication with automobiles and/or humans. The mobile communications have also become adaptable not only to transmission of data with telegraphy and/or telephones but also to transmission of computer data and multimedia contents such as images.

[0007]

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In recent years, size and cost reductions of a
mobile terminal are rapidly being improved with
increasing fabrication technologies and the like. Also,
the mobile terminal is increasingly being personalized
like a mobile phone with expanding information
communication services and the like. Further, mobile
terminal users are being on an increase more and more as
communication liberalization, communication charge
reductions and the like become attainable.

[0008]

Fundamentals of mobile communications are that a
mobile station such as an automobile phone and a mobile
phone effects detection of its nearest base station to
exchange radio waves between the mobile station and the
base station. A serviceable range of communication
adaptable to reception of the radio waves from one base
station is called a cell. The cell is typically in the
shape of a circle having a given radius with a base
station antenna as a center. Then, a communication
service area is configured in such a way as to dispose
the cells closely.

[0009]

Fig. 19 schematically illustrates a cell
configuration in a mobile wireless communication system
such as a cellular system that permits planar development
of a service area with a plurality of base stations. A
broad service area is configured with the plurality of
base stations (not shown) spaced at certain intervals to
continuously lay a plurality of cells distributed by each
base station as shown in Fig. 19.

[0010]

A reason why the mobile communication system is employing the cells as described above is to provide the advantages of being able to effectively use a limited frequency resource by limiting a range of reception of

5 the radio waves from the base stations to within a specific cell to ensure that a reuse of the same frequency is executable in other cells, and of achieving a size reduction and a power saving of a mobile terminal typically packaged as a battery-driven portable device by

10 adapting segmentation into cells to reduction of output of the radio waves for communication. In recent years, factors such as an increased number of mobile phone users (cellular phone users) have increasingly required a technology for accepting a large number of mobile phone

15 users as much as possible to a cell, while maximizing the effective utilization of the limited frequency resource. A single cell permits therein the existence of a plurality of mobile terminals, which are in communication with the single base station simultaneously. Thus, as

20 judging from a base station side, a multiple access, in other words, a technology for multiplexing a radio signal to detect which signal is assigned to which user or multi-user detection is required.
[0011]

25 A Frequency Division Multiple Access (FDMA), a Time Division Multiple Access (TDMA) for use in a second generation of a Personal Digital Cellular (PDC) and a Code Division Multiple Access (CDMA) for use in a third generation of the PDC have been conventionally known in

30 Japan as multiple access technologies in wireless communications.

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[0012]

The TDMA is a system, which is to carry out communication by assigning a different time slot for each mobile terminal for simultaneous communication under the condition that a communication channel is divided into sections with the time slot on a temporal axis in advance. This communication system is premised to be of digital system. In a digital mobile phone system in Japan, time-division multiplexing into three or six channels takes place.

[0013]

The FDMA is a system, which is to carry out communication by assigning a different frequency to each channel between mobile terminals for simultaneous communication or for each speech channel. Specifically, the FDMA is to use an available channel by allowing appropriate assignment thereof with a large number of communication channels arranged on a frequency axis. The FDMA is adaptable to any of analog and digital communication systems. In Japan, the FDMA is in use for automobile phones and mobile phones of an analog system.

[0014]

The CDMA is a system, which is to carry out communication by applying spectrum spreading to share a wide range of frequencies with a plurality of mobile terminals. Whenever the mobile terminals are in communication, a spreading sequence for spectrum spreading is assigned to each mobile terminal, which then transmits a communication signal after spreading of the communication signal with the spreading sequence. The CDMA allows the mobile terminals to use a common

frequency, so that all communication signals of stations other than one's own station result in interference to one's own station, and a performance of extracting a received signal out of the interference affects greatly

5 on a reception level.

[0015]

Now, a communication capacity is defined as the number of users acceptable to one channel for one cell. The most serious problem awaiting solution under the

10 wireless communication environment such as that the coexistence of a large number of mobile stations within the single cell brings about because of rapid and wide spread of the mobile communications is how an increased capacity is attained with a limited resource.

15 [0016]

The TDMA and the FDMA perform a reuse of a plurality of frequencies by assigning different frequencies to adjacent cells. A capacity of each of these systems is dependent only upon the number of channels. By contrast,

20 the CDMA uses the same frequency between and within the cells simultaneously, and thereby suffers in- and out-cell interference. Specifically, the CDMA is considered to be a system whose capacity is not dependent upon the number of channels but upon an amount of interference.

25 [0017]

The FDMA and the TDMA determine the upper limit of the number of users acceptable to one cell with reference to the number of channels obtained by segmenting a serviceable frequency bandwidth, and are thus limited in

30 capacity. Also, the FDMA and the TDMA are incapable of executing the reuse of the same frequency among the cells

adjoining to one another, and are thus considered to be
of small capacity as the whole of communication services.
[0018]

5   The CDMA effects code division using the spreading
sequence consisting of orthogonal and pseudo-orthogonal
codes, while users acceptable to one cell share the same
frequency, so that all signals for other users result in
undesired interference waves. The spreading sequence
applied to each mobile terminal is recognizable at a base
10   station side, so that the base station may detect each
user signal. Conversely, the spreading sequence applied
to other mobile terminals is not recognizable at a mobile
terminal side, so that user detection is not executable.
While it may be good if the spreading sequence is
15   completely in an orthogonal arrangement, components other
than orthogonal components are attributable to
interference components, with the result that the number
of users acceptable to one cell is smaller in proportion
to the number of channels made up of the pseudo-
20   orthogonal codes. Also, the CDMA has a tendency to use a
broad frequency bandwidth because of a need for spreading,
and is thus considered to be of small capacity although
one-frequency reuse is executable.
[0019]

25   The communication system based on the CDMA may
achieve detection of each signal, specifically, multi-
user detection by applying an interference cancellation
technology such as an interference canceller IC (See
Reference Document of Patent 1, for instance). The
30   interference canceller IC is effective in detecting all
received signals by repeating a process of demodulating,

in order of the magnitude of reception power, the
received signals that are composed of the sum of noise
and in-coming signals having made propagation from each
transmitting-side station through each propagation

5 characteristic, and of canceling one's own signal.
[0020]

When inter-cell multi-user detection is effected
with the interference cancellation technology such as the
interference canceller IC, a receiving-side station

10 detects the in-coming signal from each of in- and out-
cell transmitting-side stations on the assumption that
the in-coming signal is a desired signal, so that the
adjacent or neighboring cells themselves may share the
channel of the same frequency spatially or temporally.

15 Thus, a multi-cell configuration based on one-frequency
reuse is realizable with the TDMA and/or the FDMA and
thus makes contribution toward more efficient utilization
of the frequency and also toward an increased capacity as
in a case of the frequency of the same utilization.

20 [0021]

However, a difference in reception power between a
signal interfered with other cells and the desired signal
is supposed to be made smaller in the vicinity of a cell
boundary, leading to a case where reception of the above

25 signals with equal power occurs. Under the above
conditions, a problem of failing to achieve decoding and
cancellation with the interference canceller IC arises.
[0022]

[Reference Document of Patent 1]

30 Japanese Patent Laid-open No. 2002-84214

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SUMMARY OF THE INVENTION

[0023]

The present invention is intended to provide a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing method and a multiple code decoding method, which are of surpassing features to ensure that an expanded capacity is attainable by canceling in- and out-cell interference.

[0024]

The present invention is also intended to provide a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing method and a multiple code decoding method, which are of surpassing features to ensure that an increased capacity is attainable by performing operations with a very short frequency reuse.

[0025]

The present invention is further intended to provide a communication system, a transmitting apparatus and a transmitting method, a receiving apparatus and a receiving method, an unbalance code mixing method and a multiple code decoding method, which are of surpassing features to ensure that an increased capacity is attainable by implementing one-frequency reuse using a non-spread spectrum system.

[0026]

The present invention has been undertaken in view of the above problems, and a first aspect thereof is to provide a communication system for increasing a capacity

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by implementing one-frequency reuse using a non-spread spectrum system, wherein: a transmitting station side transmits a transmitting signal obtained by a process of segmenting transmission information into a plurality of frames, of encoding each frame, of power amplifying each encoded signal with a different amplitude and of interleaving all signals with each amplified signal collected into one; and a receiving station side reproduces of the above transmitting signal into the original segmental frames by a process of de-interleaving the above transmitting signal, of sequentially decoding codes of the signal in descending order of Signal-to-Interference and Noise power Ratio (SINR) and of re-encoding the decoded signal to carry out sequential cancellation of the re-encoded signal from the above transmitting signal.

[0027]

It is noted that the "system" specified herein means a logical aggregate that is configured with a plurality of apparatuses (or functional modules for implementation of specific functions), and it does not matter whether each apparatus and/or functional module are within a single casing or not.

[0028]

According to the communication system relating to the first aspect of the present invention, the receiving station side enables a desired wave and an undesired wave to be separated from each other by taking advantage of a difference in interleaving pattern. Thus, a multiple access is executable using a different interleaving pattern for each user. Alternatively, a non-spread

spectrum multi-cell system ensuring one-frequency reuse
may be implemented using a different interleaving pattern
for each cell.

[0029]

5   Thus, according to the communication system relating
to the first aspect of the present invention, dispersion
of interference signal power is attainable, leading to a
reduction thereof. In a case where a desired signal is
equal in reception power to an interference signal, which
10   case becomes an issue for the conventional inter-cell
multi-user detection, decoding is executable by
application of the present invention to the above case.
Also, a reduction in average transmission power is
attainable by designing the amplitude of a power
15   amplification unit in an appropriate manner.

[0030]

It is noted that the transmitting station side may
be also configured so that a rate of amplitude
amplification for each frame is changed according to a
20   decoding capability in the receiving station side. It is
also noted that the decoding capability in the receiving
station side may be determined with reference to the
number of interference signals, noise power and the
number of code words for one frame.

25   [0031]

In addition, an increase in the number of codes to
be multiplexed increases the decoding capability, but
requires a complicated processing. In this connection,
the transmitting station side is configured so that the
30   number of codes to be multiplexed is determined according
to the decoding capability or a process capability

realizable in the receiving station side.

[0032]

A second aspect of the present invention is to provide a transmitting apparatus or a transmitting method for transmitting information using a non-spread spectrum system, wherein the transmitting apparatus or the transmitting method comprises: frame segmenting means or a step of segmenting transmission information into a plurality of frames; encoding means or a step of encoding each frame; power amplification means or a step of power amplifying each encoded signal with different amplitude;

interleaving means or a step of interleaving all signals with each amplified signal collected into one; and transmitting means or a step of transmitting a transmitting signal obtained by the interleaving.

[0033]

According to the transmitting apparatus or the transmitting method relating to the second aspect of the present invention, the receiving station side enables the desired wave and the undesired wave to be separated from each other by taking advantage of a difference in interleaving pattern. Thus, the non-spread spectrum multi-cell system ensuring one-frequency reuse may be implemented using a different interleaving pattern for each cell. Also, the multiple-access is executable using a different interleaving pattern for each user.

[0034]

The power amplification means or the step may be also to change a rate of amplitude amplification for each frame according to the decoding capability in the receiving station side. It is noted that the decoding

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capability in the receiving station side may be determined with reference to the number of interference signals, noise power and the number of code words for one frame.

[0035]

In addition, the frame segmenting means or the step may be also to determine the number of codes to be multiplexed according to the decoding capability or the process capability realizable in the receiving station side.

[0036]

The transmitting apparatus or the transmitting method relating to the second aspect of the present invention takes measures to change the rate of amplitude amplification for each frame according to the decoding capability in the receiving station side, while an amplitude value is calculated from the number of interference signals, noise power and the number of codes having different amplitudes, for instance. It is noted that the reception power of the interference signal varies, so that interference power is set to be the worst. Then, calculation of an amplitude value of each code is performed on the assumption that the undesired wave is equal in power to the desired wave.

[0037]

However, it is seldom in an actual propagation path that the power of a plurality of undesired waves is all equal to that of the desired wave, resulting in a problem of causing a transmission power loss in the greater part of the propagation path conditions. Also, the cell disposition conditions and/or traffics showing positional

and temporal fluctuations do not take into consideration, so that a code design made in consideration of severe conditions of the propagation path causes a transmission power loss in a place where the propagation path is in

5   good conditions.

[0038]

     In this connection, the transmitting apparatus or the transmitting method relating to the second aspect of the present invention may further comprise propagation

10   path condition monitoring means or a step of monitoring propagation path conditions such as traffic conditions at certain intervals, wherein the power amplification means or the step may also effect updating of the amplitude value of each code at any time by changing the number of

15   considerable interference signals and/or the number of code words for one frame according to the propagation path conditions. Further, for more precise control of the amplitude value, it is also allowable to give a margin to the amplitude value. It is, however, noted

20   that when a change of the number of code words for one frame was made, it is necessary to send update information on the number of code words to a receiver side. On the contrary, when changes of the number of considerable interference signals and the amplitude

25   margin were merely made, there is no need to send any information to the receiver side.

[0039]

     The transmitting apparatus or the transmitting method relating to the second aspect of the present

30   invention treats the received signals in such a way as to broadly classify into two categories, specifically, one

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including a desired signal and a considerable
interference signal and the other including an
unconsidered interference signal, according to the
magnitude of the reception power. The "considerable
interference signal" specified herein means a
significantly primary interference signal in the received
signals so as to have a great effect on the desired
signal.
[0040]

Intervals of the amplitude rate are made narrower by
setting the limitation on the number of considerable
interference signals, with the result that a transmission
power is suppressible down to a lower level. In this
case, it is, however, noted that a large number of
undesired waves other than the considerable undesired
waves are existent as a matter of fact. Thus, a power
sum of the undesired waves having been not considered to
be the considerable undesired waves is called a residual
interference power. The residual interference power is
attributable to an increase in the noise as judging from
the receiver, leading to one of factors of degradation of
a decoding performance.
[0041]

By contrast, an increase in the number of
considerable interference signals increases average
transmission energy, while an increase in the number of
code words for one frame decreases the average
transmission energy. In this case, it is, however, noted
that the increase in the number of code words causes the
number of bits for one code to be made smaller, resulting
in degradation of the decoding capability when turbo

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codes are in use.

[0042]

Alternatively, the power amplification means or the step may be also to perform calculation of the amplitude value of each code by taking the residual interference power (composed of the power sum of undesired interference waves having been not considered to be the considerable undesired waves) into consideration. For instance, measures to allow the base station to collect information of an average residual interference power from each terminal may be taken to perform calculation of the amplitude value of each code in consideration of a value of collected average residual interference power. When the average residual interference power is of high level, a low-level code is supposed to be covered up by residual interference, resulting in inadaptability of decoding. Thus, the amplitude of the low-level code needs to be set larger. In this case, the amplitude of a high-level code is also made larger, so that measures to adjust the number of considerable interference signals, the number of codes for one frame and the amplitude margin or the like should be taken to maintain an average transmission power.

[0043]

A third aspect of the present invention is to provide a receiving apparatus or a receiving method for receiving a transmitting signal obtained by a process of encoding each frame resulting from segmentation of transmission information, of power amplifying each encoded signal with a different amplitude and of interleaving all signals with each amplified signal

collected into one, wherein the receiving apparatus or the receiving method comprises: de-interleaving means or a step of de-interleaving the above transmitting signal; decoding means or a step of sequentially decoding codes of the signal in descending order of SINR; and signal canceling means or a step of re-encoding the decoded signal to sequentially cancel the re-encoded signal from the above transmitting signal.

[0044]

According to the receiving apparatus or the receiving method relating to the third aspect of the present invention, the desired wave may be separated from the undesired wave in such a way as to de-interleave by taking advantage of a difference in interleaving pattern used for the transmitting station side. The non-spread spectrum multi-cell system ensuring one-frequency reuse may be implemented using a different interleaving pattern for each cell. Also, the multiple-access is executable using a different interleaving pattern for each user.

[0045]

Alternatively, it is also allowable to add a signal spreading process to the present system. It is, however, noted that the spreading specified herein is to reduce the power of the interference signal, and is not aimed principally at effecting user identification and separation, unlike the CDMA system.

[0046]

As has been described in detail in the above, according to the present invention, it is possible to provide the communication system, the transmitting apparatus and the transmitting method, the receiving

apparatus and the receiving method, the unbalance code mixing and the multiple code decoding method, which are of surpassing features to ensure that the increased capacity is attainable by implementing one-frequency reuse using the non-spread spectrum system. The present invention is effective in achieving user detection using the non-spread spectrum system, and is thus considered to be essentially different from the so-called CDMA system.

[0047]

According to the present invention, the dispersion of the interference signal power is attainable, leading to the reduction thereof. Thus, in a case where the desired signal is equal in reception power to the interference signal, which case becomes an issue for the problem of the conventional inter-cell multi-user detection, decoding is executable by applying the present invention to the above case. Also, the reduction in the average transmission power is attainable by designing the amplitude of the power amplification unit in an appropriate manner.

[0048]

Also, according to the present invention, an increased decoding performance with the average energy of a transmission symbol maintained is attainable by changing the amplitude value of the transmitting signal according to the propagation environment of the system.

[0049]

Further, according to the present invention, it is possible to set freely the amplitude value of each code by changing the number of codes that provide different amplitude values and/or the number of considerable

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interference signals.

[0050]

Furthermore, according to the present invention, an optimum system design is executable by changing the amplitude value of the transmitting code according to the cell disposition and congested hours and/or locations. In addition, a code design with the higher degree of freedom is also executable by providing the margin for the designed amplitude value of each code.

[0051]

Furthermore, according to the present invention, the receiver may execute the decoding process without a need for any preliminary information in such a way as to design the amplitude value of each code by changing only the number of considerable interference signals and/or the amplitude margin without changing the number of codes that provide the different amplitude values.

[0052]

Furthermore, according to the present invention, examination of the interference power of the whole system in advance is adaptable to establish an optimum parameter for determining the amplitude value of each code and thus makes contribution toward an increased decoding performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053]

The features and advantages of the present invention will become more apparent in the following description of the presently preferred embodiments of the invention taken in conjunction with the accompanying drawings, in

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which:

[0054]

Fig. 1 is a schematic diagram showing a transmission model according to a first embodiment of the present invention;

[0055]

Fig. 2 is a schematic block diagram showing a configuration of a receiver according to the first embodiment of the present invention;

[0056]

Fig. 3 a schematic diagram showing a transmitter configuration of UCM (Unbalance code mixing) according to the first embodiment of the present invention;

[0057]

Fig. 4 is a schematic diagram showing a process of decoding;

[0058]

Fig. 5 is a graphical representation of the minimum of an average $E_{rs}/(n_0/2)$ adaptable to decoding with respect to a required $E_{rs}/(n_0/2)$ of an original code when the number M of users is assumed to be 2;

[0059]

Fig. 6 is a graphical representation of the average $E_{rs}/(n_0/2)$ when the number M of users is assumed to be 3;

[0060]

Fig. 7 is a graphical representation of a range of reception power adaptable to decoding when the number N of codes to be multiplexed is assumed to be 1;

[0061]

Fig. 8 is a graphical representation of a range of reception power adaptable to decoding when the number N

of codes to be multiplexed is assumed to be 2;

[0062]

Fig. 9 is a graphical representation of a range of reception power adaptable to decoding when the number N of codes to be multiplexed is assumed to be 4;

[0063]

Fig. 10 is a graphical representation of a range of reception power adaptable to decoding when the number N of codes to be multiplexed is assumed to be 8;

[0064]

Fig. 11 is a graphical representation of characteristics of an average bit error rate when the number of undesired users is assumed to be 1;

[0065]

Fig. 12 is a schematic diagram showing a transmitter configuration of the UCM according to a second embodiment of the present invention;

[0066]

Fig. 13 is a graphical representation of a process of determining the number of considerable interference signals;

[0067]

Fig. 14 is a schematic diagram showing a modification of the transmitter configuration shown in Fig. 12;

[0068]

Fig. 15 is a flowchart showing a method for updating an amplitude value when an increase in the number of interference signals causes degradation of a decoding performance;

[0069]

Fig. 16 is a schematic diagram showing a receiver configuration according to an embodiment of the present invention;

[0070]

5   Fig. 17 is a schematic diagram showing a transmitter configuration of the UCM according to a third embodiment of the present invention;

[0071]

Fig. 18 is a flowchart showing a method for
10   calculating an amplitude value of each code in an amplitude calculation unit; and

[0072]

Fig. 19 is a schematic diagram showing a cell configuration in a mobile wireless communication system
15   that permits planar development of a service area with a plurality of base stations.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0073]

20   Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

[0074]

A. First embodiment

25   A-1. Transmission/reception System

As a multi-cell wireless communication system such as a cellular system, a non-spread spectrum system that carries out a multiple access without using any spreading sequence (or effects no CDMA) is considered in this

30   section. Specifically, the TDMA or the FDMA is applied to the multiple-access, and signals of users within the

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cell are in an orthogonal constellation.

[0075]

Also, a modulation system of Orthogonal Frequency Division Multiplexing (OFDM) is adopted. The OFDM is a
5   kind of multi-carrier transmission systems, and is to allow each carrier frequency to be set such that carriers are orthogonal to each other within a symbol interval. Further, the OFDM is effective in eliminating the influence of delayed waves and/or canceling interference
10 with other users within the same cell by inserting a guard interval. Accordingly, the OFDM causes no in-cell interference.

[0076]

In addition, the wireless communication system
15 described below is assumed to be a system ensuring one-frequency reuse. Specifically, this wireless communication system allows adjacent cells to use the same frequency, and thus involves the occurrence of inter-cell interference. The present invention is to
20 provide a technology for correctly decoding a desired signal by canceling the above inter-cell interference.

[0077]

Fig. 1 is a schematic diagram showing a transmission model according to a first embodiment of the present
25 invention. The embodiment shown in Fig. 1 assumes that a certain transmitting station (or a user A) effects multiplexing of two codes into a transmitting signal to transmit over a propagation path, and that the transmitting signal is interfered with a signal from one
30 of other stations (or a user B) in the propagation path. In the illustrated embodiment, a signal-to-power ratio is

assumed to be 4:1.

[0078]

A transmitter of the user A effects serial-to-parallel conversion of transmission information into signals I_{AX} (101) and I_{AY} (102), which are then encoded respectively with an encoder X (103) and an encoder Y (104). It is noted that the encoder X (103) may have the same configuration as the encoder Y (104).

[0079]

The encoded signals are amplified respectively by power amplification units (105) and (106) having different amplitudes. The present embodiment assumes that each of the power amplification units (105) and (106) is an amplitude amplifier required for the digital signal processing, and is not a power amplifier.

[0080]

The amplified signals AX and AY are merged through parallel-to-serial conversion, and are followed by random-interleaving over two code sections with an interleaver A (107). Thus, a signal TxA obtained by interleaving goes into a transmitting signal.

[0081]

Likewise, a transmitter of the user B who is within a cell different from that of the user A effects serial-to-parallel conversion of transmission information into signals I_{BX} (111) and I_{BY} (112), which are then encoded respectively with an encoder X (113) and an encoder Y (114). Further, power amplification of the encoded signals are effected with power amplification units (115) and (116) having different amplitudes to obtain amplified signals BX and BY, which are then merged, and are

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followed by random-interleaving with an interleaver B
(117), thereby providing an interleaved signal TxB as a
transmitting signal.

[0082]

5   It is noted that the encoder X (113) and the encoder
Y (114) may be the same as those for the user A. Also,
amplitude patterns of the power amplification units (115)
and (116) are arbitrarily determined, and may be
identical or not to those of the power amplification
10   units for the user A. For the convenience of
simplification, the present specification assumes that
amplitude patterns of 4 and 1 are equally assigned to the
power amplification units for each user.

[0083]

15   It is, however, noted that an interleaving pattern
is assumed to be unique at least within the neighboring
cells interfered with other cells. The embodiment shown
in Fig. 1 assumes that the interleaver A (107) and the
interleaver B (117) are different in their interleaving
20   patterns.

[0084]

     A non-spread spectrum multi-cell system ensuring
one-frequency reuse may be implemented using the
different interleaving pattern for each cell. Also, the
25   multiple-access is executable using the different
interleaving pattern for each user.

[0085]

     In a channel, the transmitting signals TxA and TxB
respectively from the users A and B are summed up
30   together into a signal AX+AY+BX+BY (120) as an
interference signal.

[0086]

Fig. 2 is a schematic diagram showing a configuration of a reception model adaptable to the transmitter configuration shown in Fig. 1. As described in the following, a receiver as the reception model shown is effective in receiving a signal having suffered interference over the channel to ensure that separation and detection of each signal are executable. It is, however, noted that a signal component contains no noise item.

[0087]

The transmitting signals from the users A and B are merged together to transmit to the receiver. The signal received by the receiver is the signal AX+AY+BX+BY (120) (Refer to Fig. 1).

[0088]

First of all, the received signal (120) is de-interleaved with a de-interleaver A (201) of the user A. The present embodiment assumes that the interleaving pattern is unique at least within the neighboring cell interfered with the other cells. It is noted that there is no correlation in the interleaving pattern between the user A and the user B as described above. Thus, output of the de-interleaver A (201) results in AX+(BX+BY)/2, which means that interference components decrease to half.

[0089]

Next, an output signal of the de-interleaver A (201) is supplied to a decoder X (202) for decoding. The decoder X (202) effects decoding of only a code X having the highest SINR (or the most probable code). If the reception power of a desired signal AX is substantially

higher than the power of an interference signal (BX+BY)/2, decoding of the desired signal AX is executable correctly, thereby providing a decoded signal I_{AX}.

[0090]

Now assuming that the signals from the users A and B were received with equal power, a power ratio of the desired signal AX to the interference signal (BX+BY)/2 becomes 4:2.5. Specifically, it means that the desired signal power is 1.6 times (2.0 dB) as much as the interference signal power. Thus, correct decoding is executable using a code such as a turbo code having a required Carrier-to-Interference power Ratio (CIR) of 2.0 dB or below as an original code.

[0091]

Also, the received signal (120) is de-interleaved with a de-interleaver B (211) of the user B. There is no correlation in interleaving pattern between the user A and the user B, so that output of the de-interleaver B (211) results in BX+(AX+AY)/2, which means that interference components decrease to half.

[0092]

Next, an output signal of the de-interleaver B (211) is supplied to a decoder X (212) for decoding. The decoder X (212) effects decoding of a code X that is a code having a highest SINR in the signal to be decoded. The reception power of a desired signal BX is sufficiently higher than the power of an interference signal (AX+AY)/2, so that a correctly decoded signal I_{BX} is obtainable.

[0093]

Next, components of the decoded signals I_{AX} and I_{BX}

are canceled from the received signal.

[0094]

The decoded signal I_{AX} obtained by decoding with the decoder X (202) is re-encoded with an encoder X (203) and is followed by amplification with a power amplification unit (204). An interleaver A (205) carries out interleaving with the decoded signal AX inputted together with a signal whose components are all 0 as the other signal AY to be merged. The interleaver A (205) has the same configuration and also employs the same interleaving pattern as the transmitter-side interleaver A (107). The above interleaving results in generation of a replica of the transmitting signal having only the signal component AX from the user A, so that cancellation of the signal component AX from the received signal (120) is effected with a differential unit (216), thereby providing an output signal AY+BX+BY. Specifically, when the propagation path produces fluctuations such as phasing, multiplying a replica of the propagation path fluctuations is effected.

[0095]

Likewise, the decoded signal I_{BX} obtained by decoding with a decoder X (212) is re-encoded with an encoder X (213), and is followed by amplification with a power amplification unit (214). An interleaver B (215) carries out interleaving with the decoded signal BX inputted together with a signal whose components are all 0 as the other signal BY to be merged. The interleaver B (215) has the same configuration and also employs the same interleaving pattern as the transmitter-side interleaver B (117). The above interleaving results in

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generation of a replica of the transmitting signal having only the signal component BX from the user B, so that cancellation of the signal component AX from the received signal (120) is carried out with a differential unit
5 (206), thereby providing an output signal AX+AY+BY.
[0096]

Finally, decoding of the signals AY and BY of the second highest power level from each transmitter is effected. First of all, the output signal (AX+AY+BY) of
10 the differential unit (206) is de-interleaved with a de-interleaver A (207) again. The de-interleaver A (207) has the same configuration and also employs the same interleaving pattern as the de-interleaver A (201).
[0097]

15 The output of the de-interleaver (207) results in AX+BY/2 and AY+BY/2, which mean that the power of the interference signal BY decreases to half. Next, the decoder Y (208) carries out decoding of a code Y having a higher SINR of the signal AY+BY/2. It is noted that if a
20 difference between the reception power of the desired signal AY and the power of the interference signal BY/2 is sufficiently large, correct decoding of the desired signal AY is executable with the decoder Y (208), thereby providing a decoded signal I_{AY}.
25 [0098]

Likewise, the output signal (AY+BX+BY) of a differential unit (216) is de-interleaved with a de-interleaver B (217) again. The de-interleaver B (217) has the same configuration and also employs the same
30 interleaving pattern as the de-interleaver B (211).
[0099]

29

The output of the de-interleaver B (217) results in
BX+AY/2 and BY+AY/2, which mean that the power of the
interference signal AY decreases to half. Next, a
decoder Y (218) carries out decoding of a code Y having a
5   higher SINR of the signal BY+AY/2. It is noted that if a
difference between the reception power of the desired
signal BY and the power of the interference signal AY/2
is sufficiently large, correct decoding of the desired
signal BY is executable with the decoder Y (218), thereby
10   providing a decoded signal I_{BY}.
[0100]

    With the above procedure, all the signals I_{AX}, I_{AY},
I_{BX} and I_{BY} having been transmitted from the users A and B
are decoded.
15   [0101]

    While the above embodiment is configured so that
decoding and cancellation of the signals in descending
order of SINR are continuously performed with all the
received signals of the users as input to the first stage
20   de-interleaver A (201) and the first-stage de-interleaver
B (211), the scope of the present invention is by no
means limited to the above embodiment. Alternatively,
iterative decoding is also applicable to increase a
decoding accuracy, for instance. A procedure of the
25   iterative decoding is described in the following.
[0102]

    First of all, decoding of AX is carries out, and
cancellation of AX from the received signal AX+AY+BX+BY
with the differential unit (216) follows, thereby
30   providing the signal AY+BX+BY.
[0103]

Next, the signal obtained by cancellation of AX to
the de-interleaver B (211) for the user B is inputted,
thereby providing the signal BX+AY/2. This signal
BX+AY/2 is a signal resulting from cancellation of the
5   interference component AX, so that decoding of BX is
effected with increased accuracy.
[0104]

Likewise, BX is decoded, and cancellation of BX from
the received signal AX+AY+BX+BY with the differential
10   unit follows, thereby providing the signal AX+AY+BY.
Then, this signal AX+AY+BY to the de-interleaver A (201)
for the user A is inputted, thereby providing the signal
AY+BY/2. This signal AY+BY/2 is a signal resulting from
cancellation of the interference component BX, so that
15   decoding of AX is effected with increased accuracy.
[0105]

As described above, the iterative decoding is
executable over the users in such a way as to offer the
decoding result of each user to the users each other,
20   specifically, the decoding result of one user to the
other user as input therefor.
[0106]

In addition, the iterative decoding is also
applicable to inter-code decoding of codes of different
25   stages (such as codes amplified with the power
amplification units having different amplitudes). In the
embodiment shown in Fig. 2, a decoding process is
completed in such a way as to effect decoding in order of
AX and AY. Decoding of BX and BY is executable by
30   adapting, to input to the first-stage de-interleaver
(211) for the user B, signal components obtained by

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canceling AX and AY from the received signal (120) after
re-encoding of the decoded signal I_{AY} obtained by the
above decoding process into AX and AY.

[0107]

5   A-2. How to set amplitudes of the power amplification
unit

The code multiplexing system in Inter-Cell Multi-
User Detection (IC-MUD) having been described with
reference to Figs. 1 and 2 is herein called Unbalance
10   Code Mixing (UCM). The IC-MUD is one of approaches to
implementation of one-frequency reuse by effecting
detection, decoding and cancellation of co-cell
interference in a system of in-cell orthogonal
arrangement of the FDMA or TDMA. The UCM is also a code
15   multiplication/interference cancellation method for
simultaneously decoding a plurality of signals received
with equal power.

[0108]

Fig. 3 is a schematic diagram showing a transmitter
20   configuration of the UCM. Referring to Fig. 3, assume
that M is the number of users (or the number of
interference signals), and N is the number of codes to be
multiplexed with the UCM (or the number of code words for
one frame). It is noted that the cell is in an in-cell
25   orthogonal arrangement and thus causes no interference,
so that all the users are assumed to be in different
cells, for the convenience of simplification of the
following description.

[0109]

30   Transmission data is subjected to serial-to-parallel
conversion, and is then encoded with the encoder. The

encoded transmission data is multiplied by the amplitude determined for each code word in the power amplification unit, and is followed by time multiplication with a multiplexer MUX.

5 [0110]

The power amplification unit multiplies the k-th code word by an amplitude value $\sqrt{a^{(k)}}$ (provided that $0<k<N-1$). An amplitude calculation part performs calculation of the amplitude value from the number of
10 interference signals, the number of code words for one frame and noise power.

[0111]

Then, the transmission data is interleaved over N pieces of codes successively with an interleaver L_m, is
15 then subjected to QPSK modulation, for instance, and is followed by OFDM modulation together with a pilot symbol into a transmitting signal. In Fig. 3, there is shown an embodiment using Quadrature Phase Shift Keying (QPSK) as a modulation method. It is noted that random
20 interleaving having a different pattern for each cell is adapted to the above interleaving. Also, the pilot symbol is assumed to be a unique orthogonal code for each cell.

[0112]

25 In the present embodiment, the amplitude value is calculated from the number of interference signals, the number of code words for one frame and the noise power as described above. While the above description is given on the assumption that the power ratio of the power
30 amplification unit is 4:1, a specific method for designing the power ratio, specifically, the amplitude

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value of each code is described in the following.

[0113]

The amplitude value of each code adaptable to decoding of all the signals is calculated. The transmitter sets up N pieces of codes of required SNR, that is, $E_{rs}/(n_0/2) = \rho$. It is noted that E_{rs} represents signal energy for one real number, and n_0 is power spectrum density at the opposite sides of noise. After the energy for one real number of the k-th code $C^{(k)}$ is defined as $E_{rs}^{(k)}$ ($E_{rs}^{(k)} > E_{rs}^{(m)}$, k>m), interleaving over the N pieces of codes for transmission is effected. Assume that a receiving end has received the signals of M users (M being the number of users) with the equal level of reception power.

[0114]

It is noted that the cell is in the in-cell orthogonal arrangement, so that interference is supposed to be caused by other cells. Also, assume that dispersion of noise added per one real number is $n_0/2 = \sigma_n^2$. At this time, assuming that cancellation of all codes from $C^{(N-1)}$ to $C^{(k+1)}$ of the transmitter was achieved after decoding thereof, the requirements adaptable to decoding of $C^{(k)}$ are given by the following expression.

[0115]

$$E_s^{(k)} > \rho\left(\sigma_n^2 + \frac{M-1}{N}\sum_{j=0}^{k} E_s^{(j)}\right) \qquad (1)$$

[0116]

Fig. 4 shows a process of the above decoding. In Fig. 4, assume that the number N of codes to be

multiplexed for each user is 4, and the number M of users equal in reception power is 3. It is noted that the illustrated embodiment assumes that the interference signal includes no interference signal whose reception power is other than the above equal reception power.

[0117]

A left section of Fig. 4 shows energy per symbol for each user when de-interleaving of a certain desired wave was carried out. The undesired wave is different from the desired wave in random interleaving pattern, so that certain interference signal energy applied to the desired signal having been de-interleaved results in an average of energies of the codes of all the levels. The number of undesired signals is M-1, so that whole interference energy is obtained by multiplying the above energy by M-1. Thus, energy of $E_{rs}^{(k)}$ is determined according to the above expression.

[0118]

When reception of all the codes with the energy satisfying the above decoding requirements is attained, all the user's codes $C^{(3)}$ having the energy of $E_{rs}^{(3)}$ are decoded. At this time, each code energy at a time when cancellation of all the user's codes $C^{(3)}$ is completed is obtained as shown in a right section of Fig. 4.

[0119]

It is noted that each of portions described in a hatching manner represents cancelled signal energy. It may be found that cancellation of the code $C^{(3)}$ of the interference signal results in a decrease of the energy of the interference signal. Thus, decoding of a code $C^{(2)}$ having the energy of $E_{rs}^{(2)}$ is next executable. In this

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manner, sequential decoding of the codes in descending order of SINR is carried out.

[0120]

The minimum $E_{rs}^{(k)}$ adaptable to decoding of all the codes is calculated by solving a recurrence formula with the above expression (1) changed to have the equality sign, and may be given by the following expression (2). The amplitude value $a^{(k)}$ to be multiplied by the k-th code word is in proportion to $E_{rs}^{(k)}$.

[0121]

$$E_s^{(k)} = \rho \sigma_n^2 \left(\frac{1}{1 - \rho(M-1)/N} \right)^{k+1} \quad (2)$$

[0122]

On the assumption that the number M of users is 2, the worst case where both the users are equal in reception power is considered (since higher reception power of the interference signal enables the interference signal to be decoded more easily). Fig. 5 shows the minimum of average $E_{rs}/(n_0 /2)$ adaptable to decoding with respect to required $E_{rs}/(n_0/2)$ of an original code. The greater the number N of codes to be multiplexed is, the smaller the average $E_{rs}/(n_0/2)$ is, while a substantially convergence of the above minimum is attained when N=16.

[0123]

Fig. 6 shows average $E_{rs}/(n_0/2)$ when the number M of users is assumed to be 3. Fig. 6 also takes into account a case where all the users are equal in reception power. It is found that higher average $E_{rs}/(n_0/2)$ is required as compared with the case where the number M of users is 2.

[0124]

A-3. Range of reception power adaptable to decoding

A range of reception power adaptable to decoding of each code is described in the following according to the above-mentioned transmitting signal designing method.

[0125]

Assume that the number M of users is 2, the required $E_{rs}/(n_0/2) = \rho$ of the original code is 1.0 (0 [dB]), and $n_0/2$ is 1.0 (0 [dB]). Figs. 7 to 10 show the range of reception power adaptable to decoding when the number of codes N is assumed to be 1, 2, 4 and 8, respectively. It is, however, noted that in Figs. 7 to 10, values scaled at a vertical axis represent average $E_{rs}/(n_0/2)$ [dB] of a desired user and values scaled at a horizontal axis represent average $E_{rs}/(n_0/2)$ of an undesired user. Also, a power ratio range having been not adaptable to decoding is plotted in Figs. 7 to 10 with the number N of codes as parameters. The number of different plotting patterns represents N pieces of codes.

[0126]

When N=1, specifically, the present invention is not applied, a small difference in reception power between the desired user and the undesired user as shown in Fig. 7 results in inadaptability of decoding even if the reception power of the desired signal is sufficiently high. By contrast, it may be found from Figs. 8 to 10 that using the present invention with the number N of codes increased to more than one enables decoding to be executed as long as reception power is sufficiently high even if the desired user is equal in reception power to the undesired user. Specifically, an increase in the number of codes to be multiplexed increases a range

adaptable to reception and thus makes contributes toward an increased decoding capability.

[0127]

A-4. Instance of bit error rate Characteristics

Results of a computer simulation using the power amplification unit whose amplitude value is obtained by designing according to the above designing method are described in the following. It is noted that the following assumptions are employed in this section.

[0128]

(i) AWGN (Additive White Gaussian Noise) channel is used for the propagation path.

(ii) SINR of each code of the received signal is known.

(iii) Reception timings of users agree with each other.

(iv) Reception powers of users are equal (specifically, the worst conditions for multi-user detection).

[0129]

In the above simulation, a turbo code using a permutator of 3rd Generation Partnership Project (3GPP) is used for the original code. Also, the number of information bits for one code is 3456 bits, an encoding rate R is 1/2 and the number of times of iteration is 20.

[0130]

Fig. 11 shows average bit error rate characteristics when the number M of users equal in reception power is assumed to be 2, specifically, the number of undesired users is assumed to be 1. In Fig. 11, values scaled at a horizontal axis represent average $E_{rs}/(n_0/2)$ of the desired signal, and values scaled at a vertical axis represent an average bit error rate of all the codes for all the users. It is noted that the number of simulation

bits is 10M bits per code for one user. Also, this
simulation takes interference signal information into
consideration in the process of turbo code decoding, and
also performs calculation of likelihood using likelihood
5   information of the code obtained by decoding in the
former stage.
[0131]

     For comparison, Fig. 11 also shows bit error rate
characteristics of the original code ((M, N) = (1,1) in
10   Fig. 11). Assuming that the required $E_{rs}/(n_0/2)$ (= ρ) is
a value having a bit error rate smaller than 10^{-6}, it may
be found from Fig. 11 that ρ = 1.2 dB is attained.
Calculation of the energy per symbol for each code was
performed using this value according to the above
15   expression (2).
[0132]

     The intervals of the energy of each code may be made
closer as the number N of codes to be multiplexed is
increased. Accordingly, the average $E_{rs}/(n_0/2)$ required
20   for correct transmission is reduced. Also, broken lines
in Fig. 11 represent calculated average $E_{rs}/(n_0/2)$. The
reason why the simulation value is higher than this
calculated value is because decoding of the turbo code is
effected using the likelihood information of the code in
25   the former stage to provide an increased decoding
accuracy.
[0133]

B. Second embodiment

     While the above first embodiment is configured so that
30   the rate of amplitude amplification for each frame is
changed according to the decoding capability in the

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receiving station side, the amplitude value is calculated
from the number of interference signals, the noise power
and the number of codes having different amplitude values,
for instance. It is noted that the reception power of
5   the interference signal varies, so that the interference
power is set to the worst value. Then, calculation of
the amplitude value of each code is performed on the
assumption that the undesired wave is equal in reception
power to the desired wave.
10   [0134]

However, it is seldom in the actual propagation path
that the power of the plurality of undesired waves is all
equal to that of the desired wave, resulting in a problem
of causing a transmission power loss in the greater part
15   of the propagation path conditions. Also, the cell
disposition conditions and/or traffics showing positional
and temporal fluctuations do not take into consideration,
so that code design made in consideration of the severe
conditions of the propagation path causes a transmission
20   power loss in a place where the propagation path is in
good conditions.
[0135]

An actual cellular system is by no means limited in
cell disposition to standardized methods, and produces
25   fluctuations in congested conditions of the traffics
depending on locations and/or hours. In this connection,
a second embodiment of the present invention is
configured so that updating of the amplitude value of
each code is carried out according to the calculation
30   with the above expression (2) by monitoring the
conditions such as traffic conditions at certain

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intervals to change the number of primary interference signals and/or the number of code words for one frame according to the above conditions.

[0136]

5   It is, however, noted that when a change of the number of code words for one frame was made, it is necessary to send update information on the number of code words to the receiver side. By contrast, when changes of the number of considerable interference

10   signals and an amplitude margin were only made, there is particularly no need to send any information to the receiver side (how to adjust the amplitude margin will be described later).

[0137]

15   Fig. 12 is a schematic diagram showing a transmitter configuration of the UCM according to the second embodiment of the present invention. In Fig. 12, assume that M is the number of users (the number of interference signals), and N is the number of codes to be multiplexed

20   with the UCM (the number of code words for one frame). It is noted that the cell is in the in-cell orthogonal arrangement and thus causes no interference, so that all the users are assumed to be in different cells, for the convenience of simplification of the following

25   description.

[0138]

       Transmission data is subjected to serial-to-parallel conversion, and is then encoded with an encoder. The encoded transmission data is then multiplied by the

30   amplitude determined for each code word in the power amplification unit, and is followed by time multiplexing

with a multiplexer MUX.

[0139]

The power amplification unit multiplies the k-th code word by an amplitude value $\sqrt{a}^{(k)}$ (provided that 0<k<N-1). An amplitude calculation part performs calculation of the amplitude value from the number of considerable interference signals, the number of code words for one frame and the noise power.

[0140]

Then, the transmission data is interleaved over N pieces of codes successively with an interleaver L_m, is then subjected to QPSK (Quadrature Phase Shift Keying) modulation and is followed by OFDM modulation together with a pilot symbol, thereby providing a transmitting signal. In Fig. 12, there is shown an embodiment using QPSK is used as a modulation method. It is noted that random interleaving having a different pattern for each cell is adapted to the above interleaving. Also, the pilot symbol is assumed to be a unique orthogonal code for each cell.

[0141]

In the second embodiment, the amplitude value is calculated from the number of considerable interference signals, the number of code words for one frame and the noise power. The second embodiment treats the received signals in such a way as to broadly classify into two categories, specifically, one including a desired signal and a considerable interference signal and the other including an unconsidered interference signal, according to the magnitude of the reception power. The "considerable interference signal" specified herein means

a significantly primary interference signal in the received signals so as to have a great effect on the desired signal.

[0142]

5   Fig. 13 shows the received signals including the desired signals and all the interference signals in order of the magnitude of reception power. In calculation of the amplitude value, only the interference signals exceeding a given threshold are treated as the

10   considerable interference signal. The intervals of the amplitude ratio are made narrower by setting the limitation on the number of considerable interference signals, with the result that the transmission power is suppressible down to a lower level. In this case, it is,

15   however, noted that a large number of undesired waves other than the considerable undesired waves are existent as a matter of fact. Now, assume that a power sum of undesired waves having been not considered to be the considerable undesired waves is called a "residual

20   interference power". The residual interference power is attributable to an increase in the noise as judging from the receiver, leading to one of factors of degradation of the decoding performance.

[0143]

25   An increase in the number of considerable interference signals increases average transmission energy. By contrast, an increase in the number of code words for one frame decreases the average transmission energy. It is, however, noted that the increase in the

30   number of code words causes the number of bits for one code to be made smaller, resulting in degradation of the

decoding capability when the turbo codes are in use.
[0144]

Alternatively, it is also allowable to give the
margin to the amplitude value for finer control of the
amplitude value. Fig. 14 shows a modification of the
transmitter shown in Fig. 12. In the configuration shown
in Fig. 12, the amplitude calculation unit performs
calculation of the amplitude value from the number of
considerable interference signals, the number of code
words for one frame and the noise power. By contrast, an
amplitude calculation unit in the modification of Fig. 14
is to perform calculation further with the margin given
to the amplitude value.
[0145]

A method for updating the amplitude value in a case
where the increase in the number of interference signals
causes degradation of the decoding performance is
described in the following with reference to a flowchart
of Fig. 15.
[0146]

First of all, examination of the propagation path
conditions is made (the propagation path is being
estimated at all times in decoding) (Step S1) to
determine the number of considerable interference signals
(Step S2).
[0147]

The increase in the number of interference signals
(Step S3) increases the average energy, so that the
number of code words for one frame is increased (Step S4)
to suppress the increase in the average energy. It is,
however, noted that the change of the number of code

words for one frame was made, update information of the number of code words is sent to the receiver side (Step S5).

[0148]

5   An excessive increase in the number of code words leads to degradation of the characteristics for the turbo codes (Step S6). Thus, the amplitude margin is decreased (to make a difference in amplitude value between the code words smaller) (Step S7) to prevent the average energy

10   from being increased.

[0149]

By contrast, when the number of interference signals is decreased (Step S8), the number of codes for one frame may be decreased (Steps S9 and S10) or the amplitude

15   margin may be increased to update the amplitude value (Step S11).

[0150]

Fig. 16 is a schematic diagram showing a configuration of a receiver of the UCM according to the

20   second embodiment of the present invention. The receiver shown in Fig. 16 is effective in receiving the transmitting signal from the transmitter shown in Figs. 12 and 14, and besides, is adaptable to the transmitter according to the first embodiment shown in Fig. 3. The

25   configuration and operations of this receiver are described in the following.

[0151]

A channel estimation/compensation unit carries out phase compensation of the received signal from each cell

30   with reference to channel fluctuations respectively estimated from the pilot symbols.

[0152]

Then, the received signal is de-interleaved after having been passed through OFDM modulation and QPSK modulation. Upon completion of de-interleaving of the received signals of all the users, a code word detection unit selects the code word having the highest SINR, and decoding of the selected code follows.

[0153]

The decoded data is encoded in a re-encoding unit shown in a lower stage of Fig. 16, and is followed by UCM multiplexing again. In this process, a symbol remained at present as it is not decoded is multiplexed as 0. In OFDM modulation, the pilot symbol is also treated as zero (0), and a canceller cancels of the pilot symbol from the received signal after estimated channel fluctuations are taken into consideration. The decoding and cancellation are repeatedly performed in this manner until decoding of all the required code words is achieved.

[0154]

When the decoding performance greatly changed with the traffic fluctuations and/or the increase or decrease of the number of interference stations, the receiver sends information about these conditions to the transmitter. The transmitter side recalculates the amplitude value of each code with reference to the information sent from the receiver to effect multiplexing of the codes using the updated amplitude value. Alternatively, the transmitter may perform recalculation of the amplitude value by estimating the propagation path conditions of a transmitting link with reference to one's own received propagation path conditions. In the latter

case, there is no need for any special procedure of sending information of the propagation path conditions or the like from the receiver to the transmitter.

[0155]

5   Resetting of the amplitude value of each code word at the side of the transmitter by changing the number of code words for one frame leads to a change of a frame configuration, so that it is necessary to send information about these conditions to the receiver side.

10   By contrast, when resetting of the amplitude value of each code was effected with reference to the number of considerable interference signals and the amplitude margin with the number of code words set constant, it is not necessary to send information about these conditions

15   to the receiver.

[0156]

C. Third embodiment

      The above second embodiment of the present invention treats the received signals in such a way as to

20   broadly classify into the two categories, specifically, one including the desired signal and the considerable interference signal and the other including the unconsidered interference signal according to the magnitude of the reception power. Specifically, the

25   significantly primary interference signal in the received signals so as have a great effect on the desired signal is treated as the considerable interference signal to perform calculation of the amplitude value of each code with reference to the number of considerable interference

30   signals.

[0157]

The intervals of the amplitude ratio are made narrower by setting the limitation on the number of considerable interference signals, with the result that the transmission power is suppressible down to a lower

5   level. By contrast, it is noted that a large number of interference waves other than the considerable undesired waves are existent as a matter of fact. The "residual interference power" composed of the power sum of the undesired waves having been not considered to be the

10   considerable undesired waves is attributable to the increase in the noise as judging from the receiver, leading to one of factors of degradation of the decoding performance.

[0158]

15   In this connection, the third embodiment of the present invention is configured so that the amplitude value of each code is determined in consideration of the interference power of the whole system, inclusive of the residual interference power, in calculation of the

20   amplitude value of each code. Fig. 17 is a schematic diagram showing a transmitter configuration of the UCM according to the third embodiment of the present invention. In Fig. 17, assume that M is the number of users (the number of interference signals), and N is the

25   number of codes to be multiplexed using the UCM (the number of code words for one frame). It is noted that the cell is in the in-cell orthogonal arrangement and thus causes no in-cell interference, so that all the users are assumed to be in different cells, for the

30   convenience of simplification of the following description. The configuration and operations of the

transmitter shown in Fig. 17 are described in the following.

[0159]

     Transmission data is subjected to serial-to-parallel conversion and is then encoded with an encoder. The encoded transmission data is multiplied by the amplitude determined for each code word in the power amplification unit and is followed by time multiplexing with a multiplexer MUX.

[0160]

     The power amplification unit multiplies the k-th code word by the amplitude value $\sqrt{a^{(k)}}$ (provided that $0<k<N-1$). An amplitude calculation unit performs calculation of the amplitude value from the number of considerable interference signals, the number of code words for one frame and the noise power.

[0161]

     Then, the transmission data is interleaved over N pieces of codes successively with an interleaver L_m, is then subjected to QPSK modulation, for instance, and is followed by OFDM modulation together with the pilot symbol. In Fig. 12, there is shown an embodiment using QPSK as a modulation method. It is noted that random interleaving having a different pattern for each cell is adapted to the above interleaving. Also, the pilot symbol is assumed to be a unique orthogonal symbol for each cell.

[0162]

     The amplitude calculating unit in the third embodiment is to perform calculation of the amplitude value from the amplitude margin and average residual

interference power, in addition to the number of considerable interference signals, the number of code words for one frame and the noise power. The average residual interference power specified herein is

5   equivalent to the average value of the power with respect to the interference signals other than the desired signals and the considerable interference signals shown in Fig. 13.

[0163]

10   A method for calculating the amplitude value of each code in the amplitude calculation unit is described with reference to Fig. 18.

[0164]

      The number M of considerable interference signals

15   may be determined with reference to each user reception power detected in the channel estimation process performed at the time of signal reception, for instance. As judging from the embodiment shown in Fig. 13, the number M of considerable interference signals is that

20   obtained by subtracting the number of desired signals (=1) from the number of signals exceeding the given threshold.

[0165]

      Also, assumed noise power n_0 basically consists of a

25   thermal noise, and is thus subject to no fluctuation (specifically, is treated as a constant).

[0166]

      The average residual interference power is equivalent to the average value of the unconsidered

30   interference signal power, and is here applied to calculation of the amplitude value by increasing the

dispersion of noise σ_n^2.

[0167]

 The amplitude margin is determined with reference to the SINR obtained by the channel estimation process and/or the error characteristics obtained at the time of signal decoding. Multiplying the required SNR, that is, ρ by a certain value is adapted to adjustment of the amplitude margin.

[0168]

 First of all, the dispersion of noise σ_n^2 is determined in consideration of the average residual interference power (Step S21).

[0169]

 Next, the required SNR, that is, ρ is determined for adjustment of the amplitude margin (Step S22).

[0170]

 Then, the amplitude value of the code is obtained (Step S23) by calculating the above expression (2) with substitution of the number M of considerable interference signals, the number N of code words for one frame and the assumed noise power n_0, together with the parameters obtained in the previous Steps S21 and S22.

[0171]

 It is noted that the receiver shown in Fig. 16 is assumed to be adaptable to the transmitter according to the third embodiment shown in Fig. 17.

[0172]

 For instance, measures to allow the base station that is operating as the transmitter according to the third embodiment to collect information of the average residual interference power from each terminal is taken

to calculate the amplitude value of each code in consideration of the collected information. When the average residual interference power is of high level, a low-level code is supposed to be covered up by the

5 residual interference, resulting in inadaptability of decoding. Thus, the amplitude of the low-level code needs to be set larger. In this case, the amplitude of a high-level code is also made larger, so that measures to adjust the number of considerable interference signals,

10 the number of codes for one frame and the amplitude margin or the like should be taken to maintain the average transmission power.

[0173]

Although the invention has been described in detail

15 with reference to the specific embodiments, it is understood by those skilled in the art that various changes and modifications of the above embodiments may be made without departing from the spirit and scope of the invention. Specifically, the above embodiments of the

20 invention are illustrative and not restrictive. The scope of the invention is therefore to be determined by the appended claims.